
I-40 ROCKSLIDE 2009
A 44-YEAR TRADITION CONTINUES…

I-40, Haywood County

- Fully closed 4 lanes at MM 2.5

- Average Daily Traffic

  22,000 Vehicles per day of which

  ~10,000 are Commercial Carriers

- Estimated Value to the World Economy

  $1,000,000 per day

Mountain History

- Formed at least 700 million years ago
- Between 400 – 500 feet tall
- Several Geologic Groups present ranging from Basement Complex (Oldest) to much younger sandstones and shady dolomite
- Highly indurated quartzite
- The Pigeon River Gorge is approximately 15 miles long

Why did the Slide Happen?

- Large amounts of rainfall
- Wedge forming planes with toe removed during original construction

- Occurred around 2 am on Oct. 25, 2009 and fully closed the highway
- Two accidents, one injury, no fatalities

Decision Process

Oh my!

What Do We Do?

What Should We Do?

What Happened?

Who Can We Call?

Have the Rocks Stopped Falling?

I'm hungry

What Day is It?

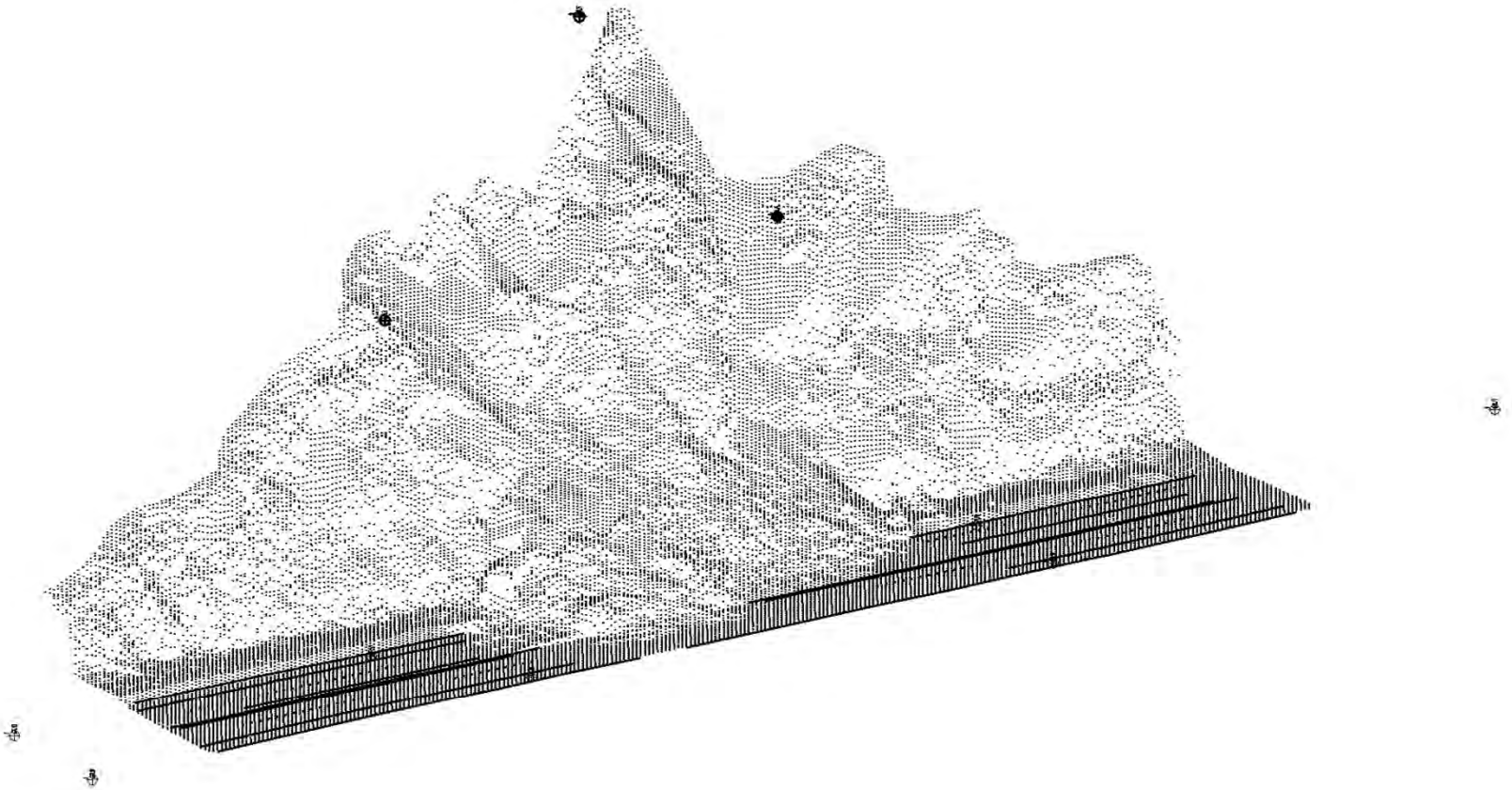
How are we going to pay for this?

Identify the Problem

- Survey the slope
- Determine the Scope/Limits of the Problem
- Determine what repair options exist and ultimately what is needed
- Who/What capabilities do the Contractors have
- Access? Safety? Success?

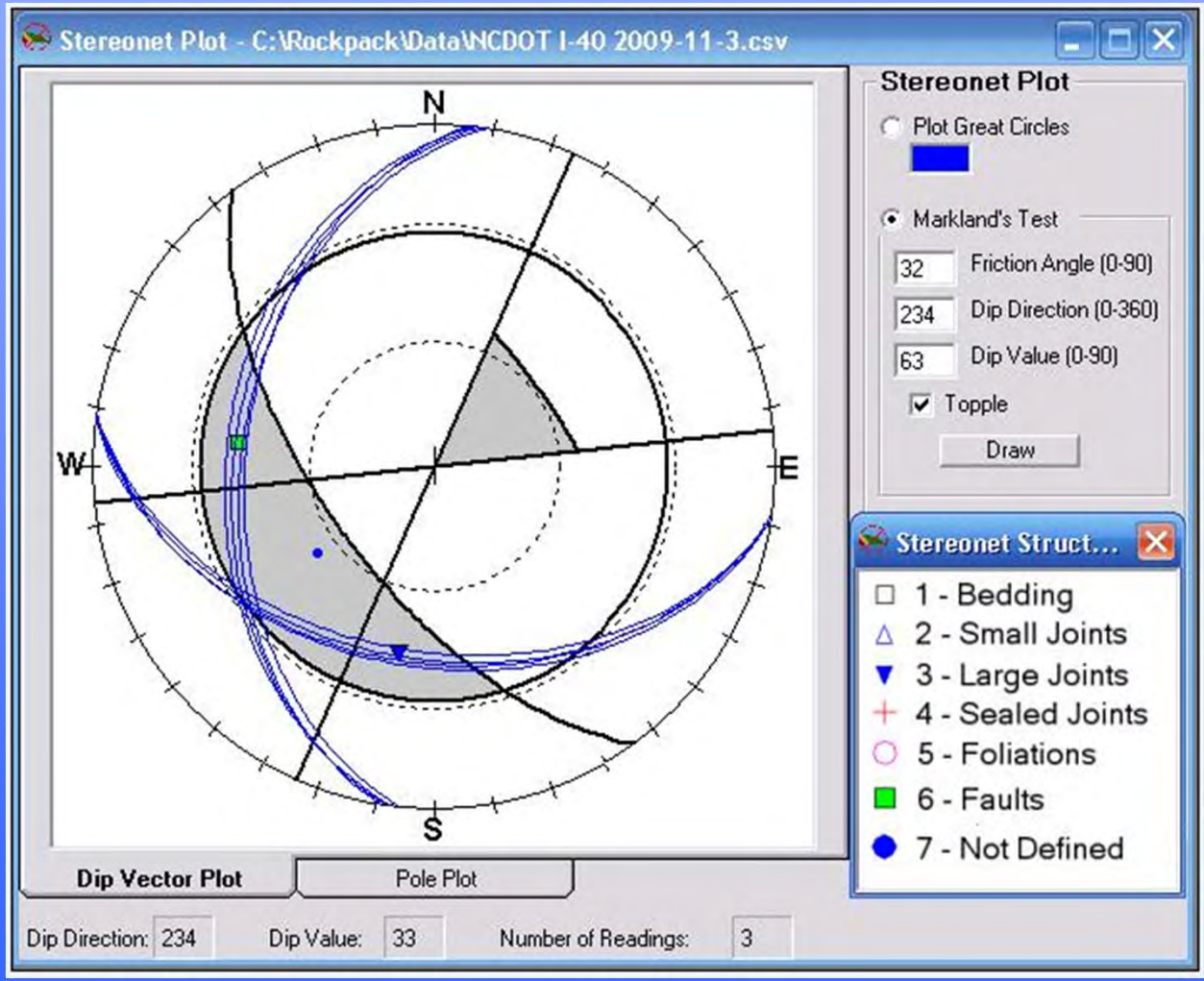
Aerial Photo with Topography

3D Model of the Slide

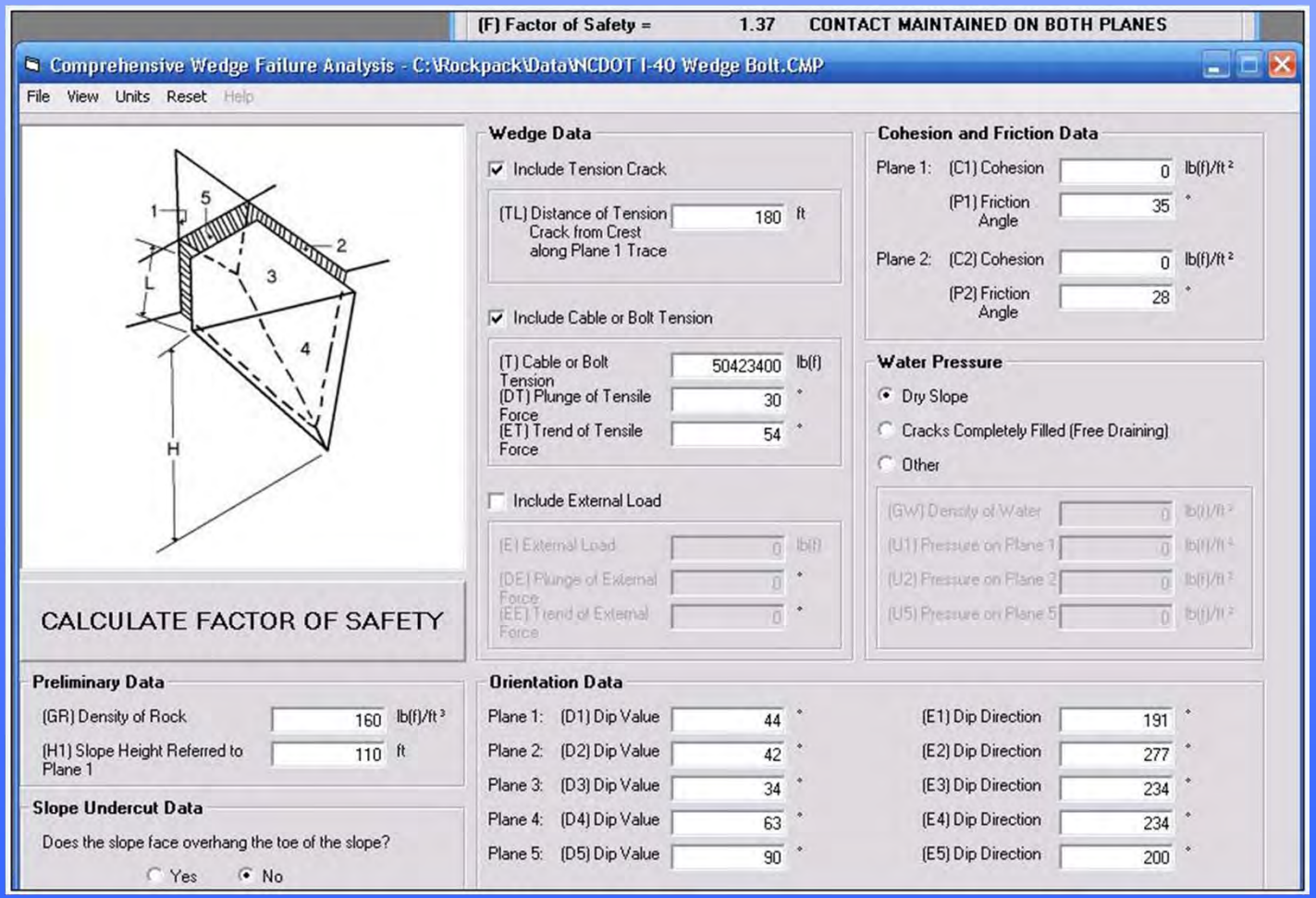


Field Data Collection

Stereonet Plot of the Failure Planes

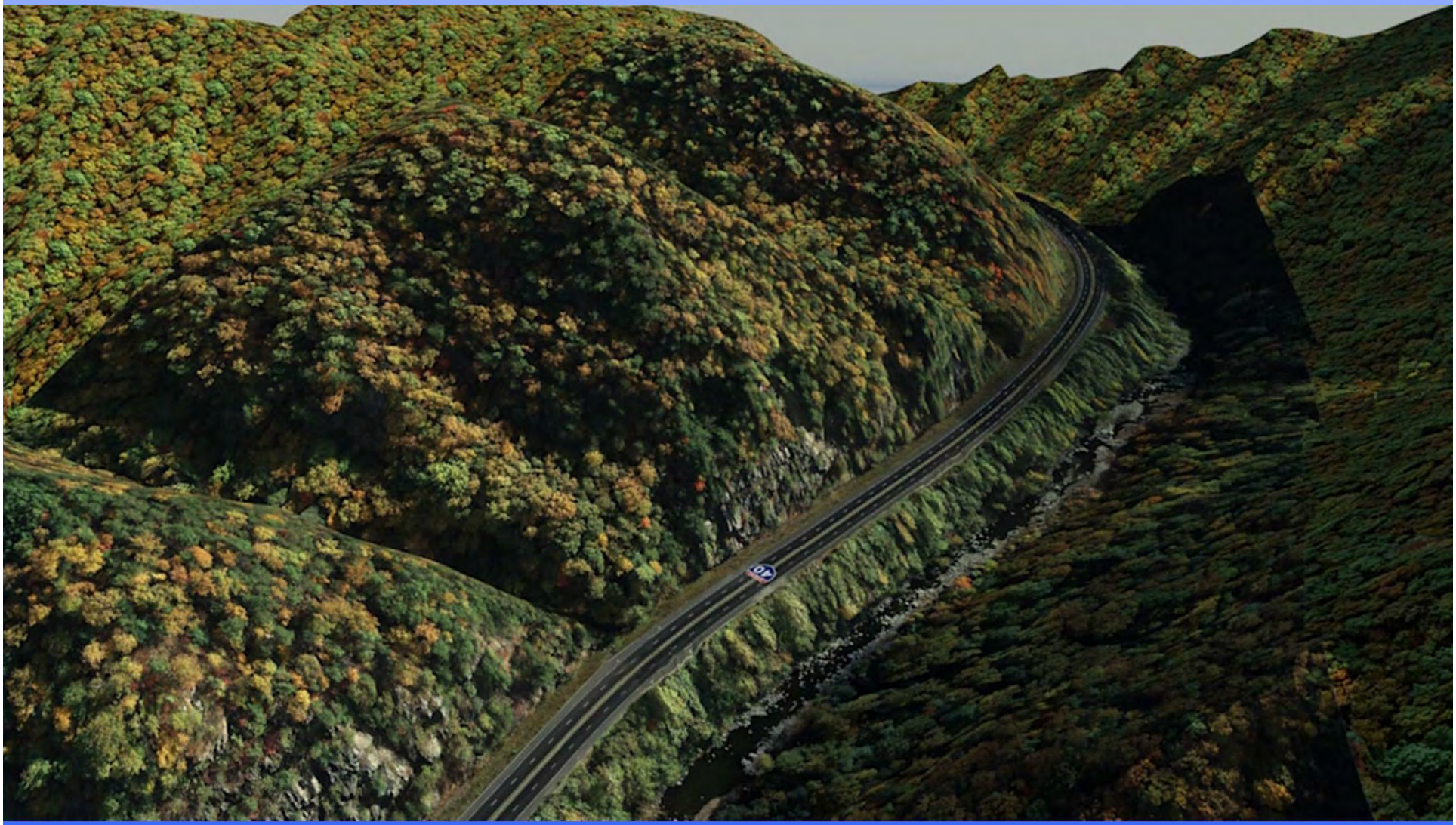


Wedge Analysis Based Field Data



Scope of Problem

- Very Large Wedge to Remove or Stabilize
- Colluvial Mass to Remove or Anchor Down


70

Drilling Pre-Split Holes to Begin Excavating the Wedge by Layers

Challenges With the Excavation Plan

- Where to start? Top? Bottom?
- Where to put the material….~350,000 yds
- Forest Service Wants it
- DOT will use it but can’t store it

The problem is it is still on the mountainside!

What to do next?

Excavate the whole wedge

~ 350,000 cubic yards

~42,000 Dump Truck Loads

~1 Football Field, 200 ft Deep

~ 16 Million $

Scale what is unstable and anchor the remainder

What kind of anchor?

How many do we need?

1 3/8” 150 KSI Threaded Bars

592 Tensioned Anchors

~8.9 Million $

Bolting Design Considerations

- Who Can Do the work?
- How will they access the site?
- How fast can they be installed?
- How large of a hole can be drilled?
- How deep can the Contractor drill….with accuracy?

HOW MANY WILL YOU NEED?

What Factor of Safety is Needed?

If we are bolting, what FS is acceptable?

1.5

10

FS =1.3

1.1

1.2

2

The Wedge was analyzed using Roc Pak III and Swedge

RockWare®
Earth Science and GIS Software

rocscience

Swedge - [1_Rock Bolt Design_active existing.swd - FS=1.27273]

File Edit View Analysis Support Statistics Window Help

Deterministic FS=1.273

Top

Perspective *

Front

Side

Wedge Information: Filter List ...

Deterministic Analysis
Factor of Safety: 1.2727

Wedge Data
Volume: 9135373.436 ft3
Weight: 770111.98 tons
Area (joint1): 100723.62 ft2
Area (joint2): 108362.29 ft2
Area (slope): 19849.91 ft2
Area (upper face): 189097.86 ft2
Area (tension crack): 27010.44 ft2
Normal Force (joint1): 354333.72 tons
Normal Force (joint2): 401801.85 tons
Normal Stress (joint1): 3.52 t/ft2
Normal Stress (joint2): 3.71 t/ft2
Shear Strength (joint1): 2.46 t/ft2
Shear Strength (joint2): 2.14 t/ft2
Driving Force: 415972.79 tons
Resisting Force: 529422.61 tons
Mode: Sliding on joints 1&2

Line of Intersection
Plunge: 34.26 deg
Trend: 236.15 deg
Length: 493.05 ft

Trace Length
Joint1: 495.00 ft
Joint2: 514.87 ft
Tension Crack: 427.32 ft

Persistence
Joint1: 546.03 ft
Joint2: 680.62 ft

3_Active_2.swd - FS=1.36947* | 1_Rock Bolt Design_active existing.swd - FS=1.27273

Ready MAXIMUM 47.5, 488

Start | Search Results | Swedge - [1_Rock Bolt... | 9:34 AM

Number of Bolts Needed based on the Desired Factor of Safety

Assuming 140 kip anchors

10 ~*10,838*

1.5 ~*1542*

FS =1.3 ~ 592

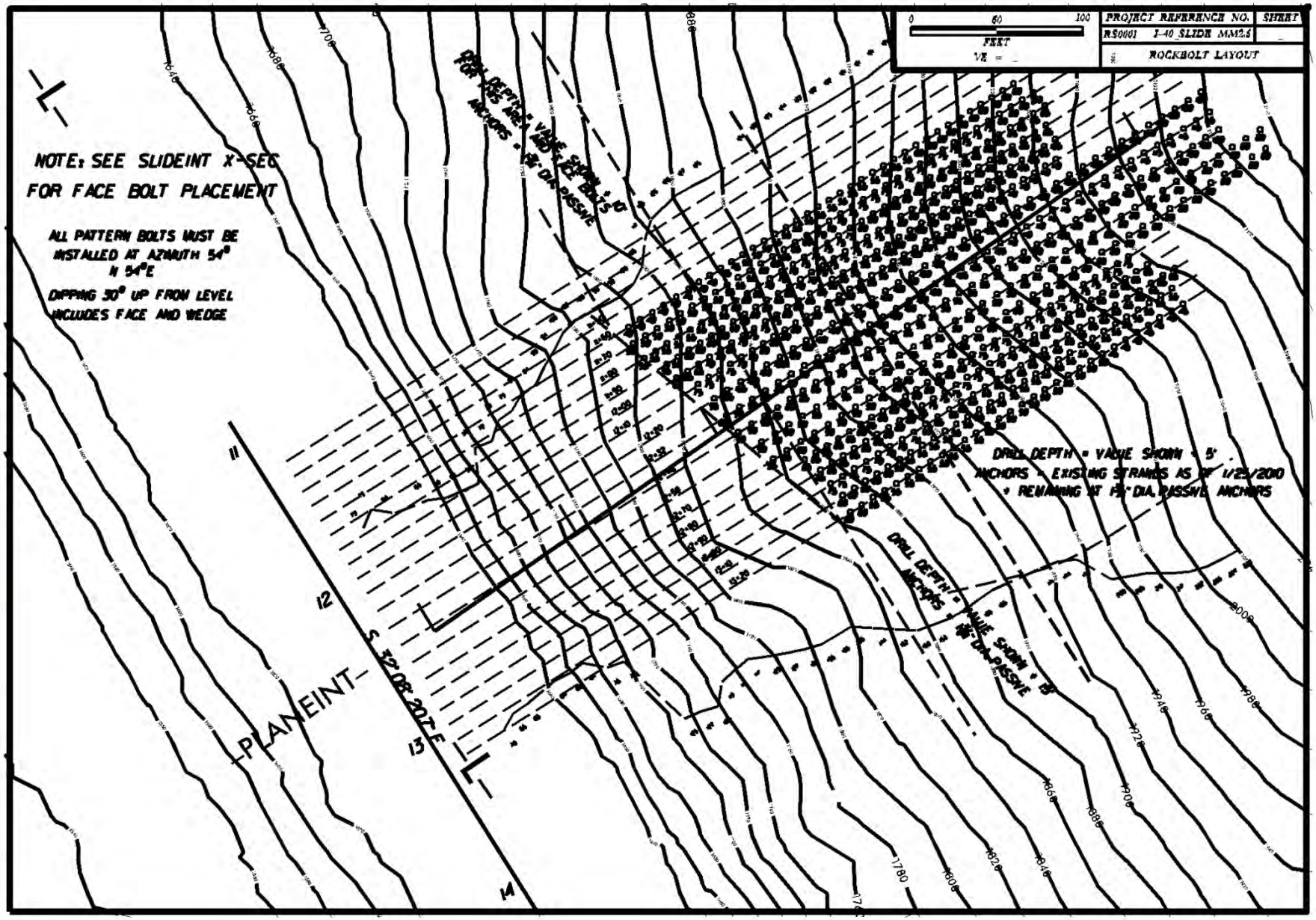
1.1 ~ 100

1.2 ~ *197*

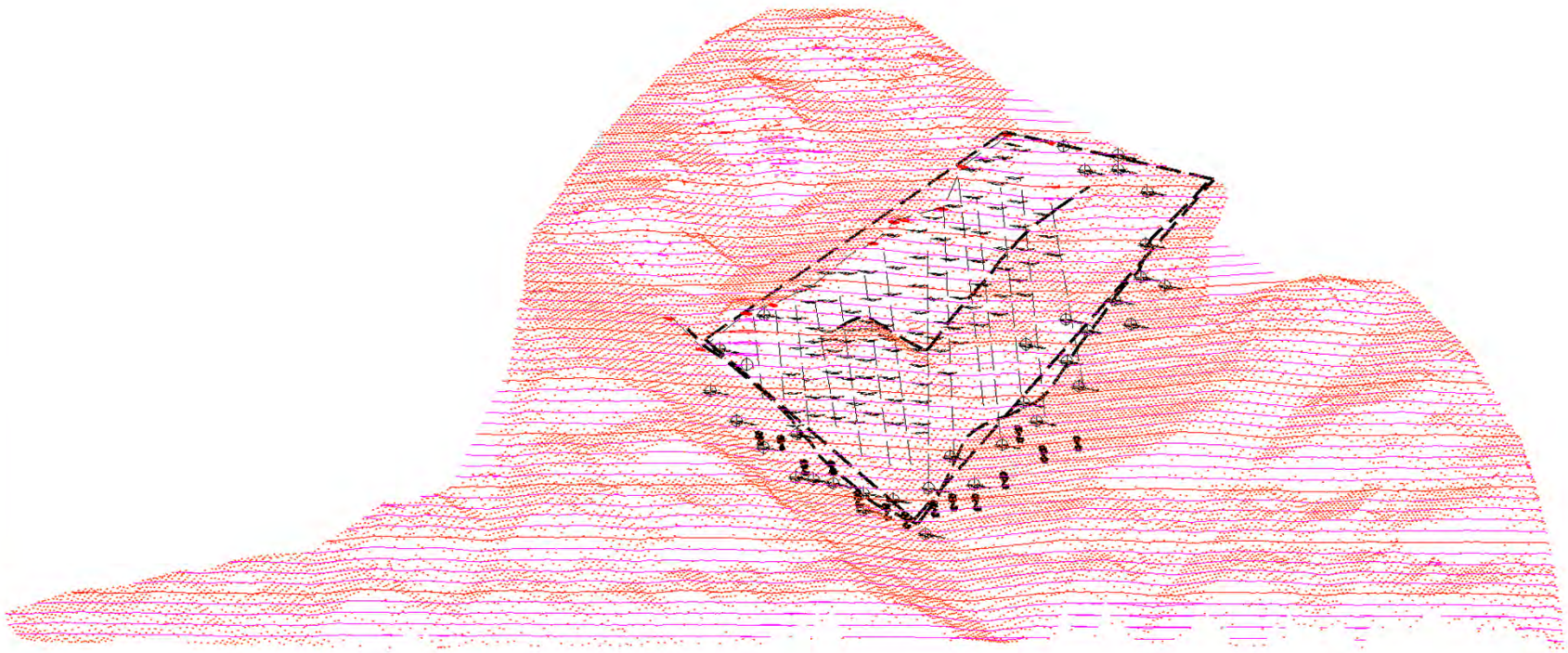
2 ~ *3291*

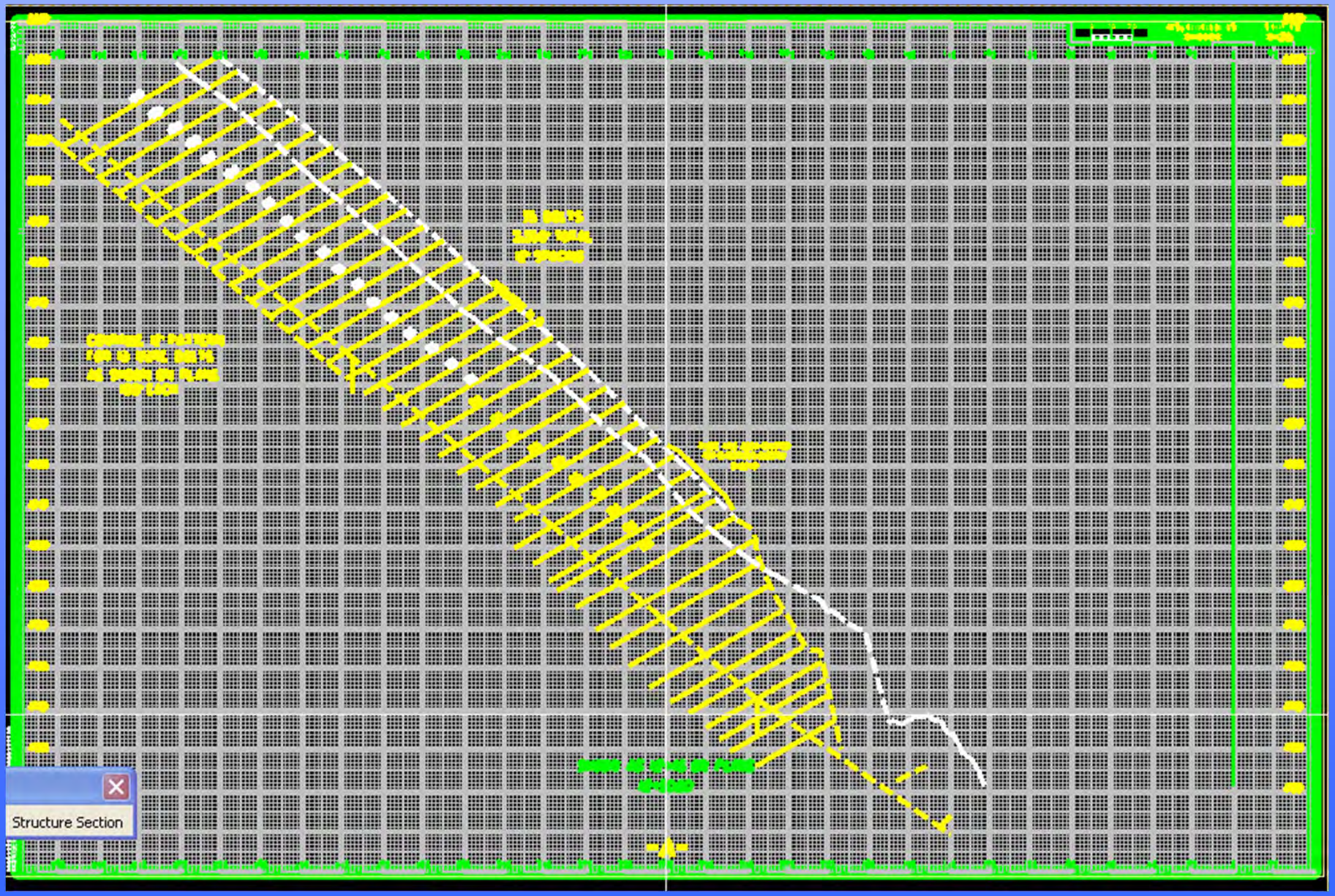
Active Anchor Design

- 592 Tensioned Rock Bolts
- Lengths Vary from 70 feet to 125 feet
- Bonded Zone, 10 feet minimum
- Anchors Tensioned to 140 kips
- Anchors Bars – Grade 150, 1 3/8” Diameter, ~ 190 kips Min. Yield, Weight - 5.7 lbs/ft


PROJECT REFERENCE NO.
SHEET
RS0001 I-40 SLIDE MM23
ROCKBOLT LAYOUT
0 50 100
FEET
VE = _
NOTE: SEE SLIDEINT X-SEC
FOR FACE BOLT PLACEMENT
ALL PATTERN BOLTS MUST BE
INSTALLED AT AZIMUTH 54°
N 54°E
DIPPING 30° UP FROM LEVEL
INCLUDES FACE AND WEDGE
DRILL DEPTH = VALUE SHOWN + 5'
ANCHORS = EXISTING STRANDS AS OF 1/25/200
+ REMAINING AT 1½" DIA. PASSIVE ANCHORS
DRILL DEPTH = VALUE SHOWN + 5'
ANCHORS = 1½" DIA. PASSIVE
PLANEINT
S 52°08' 20"E
11
12
13
14
1780

Slide Face: LiDAR Scan




Structure Section

Winter Weather

Between December and February, there was ~25” of snow
Which is ~15” more than the average

Anchor Installation

After your anchor locations are drilled and inspected for orientation, inclination and depth, it is time to install your anchor bars.

HOW?

Carry them up the slope?

Fly them in?

Strand Anchor Option

- The contractor proposed using strand anchors for anchors that were longer than 60 feet.
- The option was reviewed and ultimately accepted

Strand Anchor Requirements

Capable of obtaining the same capacity as the bar anchors

Highly machined bearing face at the anchor head location


01/28/2010

Anchor Testing

All tensioned anchors were incrementally loaded and tested for capacity, elongation, short term creep and long term creep, if required.

Was a hybrid provision between “proof testing” and “performance testing” common in PTI guidelines.


PETZL

Problems with the Strand Anchors

- These anchors were selected for the deeper anchor locations
- The head alignment is very precise, better suited toward structures
- The jacks weigh in at ~300 + pounds
- Some anchor locations had depths where the elongation would exceed the capacity of the jacks….what now?

Two Basic Types of Anchors

Active Anchors

Load is applied to the sliding plane to increase the friction between the masses

Have both bonded and unbonded zones

Passive Anchors

The anchors are not preloaded and engage with very limited movement

The entire bar is bonded

Why Change?

Challenges with initial drilling

Very time consuming

Weather issues

Load testing issues

More water in the slope than was included in the initial design ~50% vs. 25%

Geologic characteristics make Passive design acceptable to NCDOT

Switch from Engineering to Geology to accept a passive anchor design:

Passive Design

- Reanalyzed the sliding mass with respect to waviness and roughness along the failure surface as well as the persistence of the failure plane
- Contractors ability to effectively drill a 4.5 inch diameter hole
- The ability to install a larger diameter bar

Passive Design

544 bolts of which 130 were tensioned and installed above the passive system

1 ¾”, 150 KSI Threaded Bars with a minimum yield of 320 kips, 9.0 lbs/ft

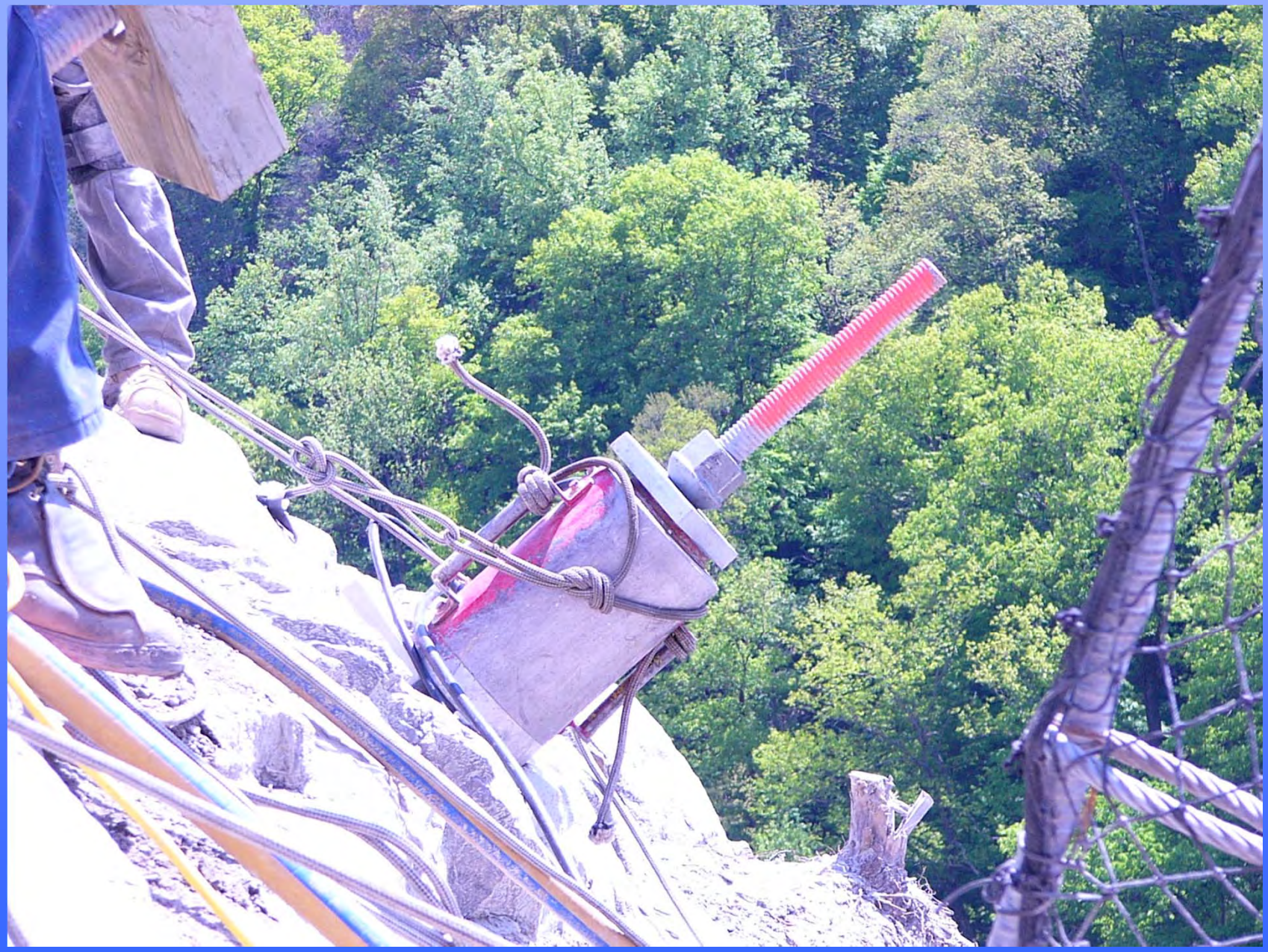
Increased the bond depths below the wedge plane to 20 feet

Requirement of the Passive System

BOND STRENGTH

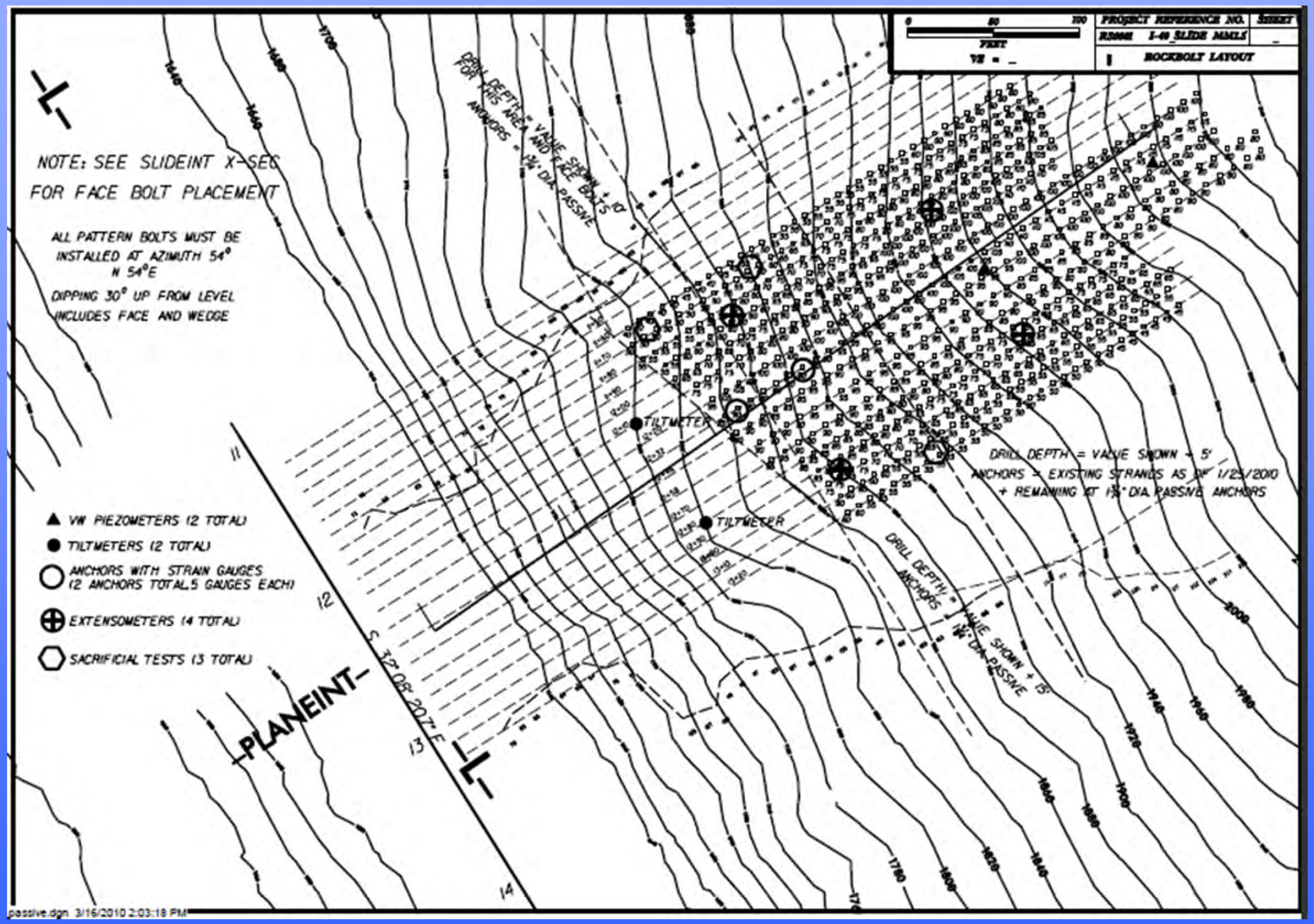
Assumed 150 psi in design

Performed 4 pullout tests, each with a 2 ft bond zone, and determined there was greater than 400 psi present



Future Monitoring of the Slide

- Four Roctest Bor-ex Extensiometers
- Two Vibrating Wire Piezometers
- Two bar anchors instrumented with 5 vibrating wire strain gauges
- Two Tuff Tilt 801 tiltmeters (+/- 3 degrees) for the face
- All wired to a datalogger with cell phone access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N 54°E
DIPPING 30° UP FROM LEVEL
INCLUDES FACE AND WEDGE
VW PIEZOMETERS (2 TOTAL)
TILTMETERS (2 TOTAL)
ANCHORS WITH STRAIN GAUGES
(2 ANCHORS TOTAL,5 GAUGES EACH)
EXTENSOMETERS (4 TOTAL)
SACRIFICIAL TESTS (3 TOTAL)
PLANEINT
TILTMETER
TILTMETER
DRILL DEPTH = VALUE SHOWN + 5'
ANCHORS = EXISTING STRANDS AS OF 1/25/2010
+ REMAINING AT 1¾" DIA PASSIVE ANCHORS
DRILL DEPTH = VALUE SHOWN + 15'
ANCHORS = 1¾" DIA PASSIVE
DRILL DEPTH = VALUE SHOWN + 10'
FOR THIS AREA AND FACE BOLTS
ANCHORS = 1¾" DIA PASSIVE
S 12°08' 20" E
passive.dgn 3/16/2010 2:03:18 PM

Tuff Tilt Meter

Bolted Wedge Face

Meshed and Anchored Colluvium

Additional Work in the Gorge

5 additional sites were scaled and received anchors (active) and mesh as needed


I-40 Rockslide and Rehab Sites
Scale: 1"=400'
Contours: 100'
County: Haywood
Photo: 2008 Haywood Co. NAIP
Note: Contours generated from NCFMP Bare Earth LIDAR
Note: All Rehab Site locations are approximate

Questions?

Involved parties:
Phillips and Jordan Construction, General Contractor
Janod, Ltd, Drilling and anchor installation
NCDOT Geotechnical Engineering
NCDOT Division 14 Construction staff
Fisher and Strickler Rock Engineers, Design Peer Review

Additional Information

Jody Kuhne, LG, PE

jkuhne@ncdot.gov

828-298-3228